Satellite Observations of Surface Fronts, Currents and Winds In the Northeast South China Sea

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LONG-TERM GOALS

The long-range goal of this proposal is to improve our understanding of surface currents and fronts in the northeast South China Sea and their influence on acoustic propagation across the shelfbreak in this low-latitude setting. We are using satellite measurements of sea surface temperature, color, height and winds to identify and analyze the regional surface fronts and mesoscale eddy features and collaborate with other ASIAEX investigators to reach this goal.

OBJECTIVES

Relatively little is known about the general circulation and fronts in the northeast South China Sea. Past work suggests a northeastward current over the outer shelf (the South China Sea Warm Current) and a southwestward current over the slope containing Kuroshio water from the Luzon Strait, however, there exist few *in situ* direct current measurements to support this schematic. Previous AVHRR imagery showed that the Kuroshio can bifurcate in the Luzon Strait, with some of its transport entering the South China Sea west of Taiwan. Wind stress (Farris and Wimbush, 1996) and wind stress curl (Metzger and Hurlburt, 2001) have been shown to be relevant to the penetration of the Kuroshio and subsequent shedding of large mesoscale eddies, which may influence flow over the Chinese continental margin directly.

The Asian Seas International Acoustics EXperiment (ASIAEX) was developed to investigate the propagation of low frequency sound across the shelfbreak in this region. As part of this program, two one-month field studies were conducted, featuring high-resolution SeaSoar/ADCP surveys and moored acoustic and physical oceanographic measurements. One objective of the physical measurements was to observe the current and thermohaline fields near the shelfbreak with sufficient spatial and temporal resolution to help interpret the variability observed in the acoustic data. As part of this latter effort, we are using satellite data to help describe surface features and their evolution during the two field studies. In addition, we are using satellite data collected beyond the two field studies (limited to satellite

availability) to better understand the larger-scale surface variability in the eastern South China Sea on time scales of days to years, and the relationship between this regional variability and that observed in the two smaller-scale shelfbreak field studies.

APPROACH

We began collecting and processing AVHRR, ocean color, and altimeter data for the eastern South China Sea in January 2000, with one objective being to provide early descriptions of the surface features observed in the area of the study to ASIAEX investigators prior to the two field programs. The collection of the remote sensing data has continued for two full years (into spring, 2002). Archived data prior to the field programs (from the beginning of each satellite data stream) was obtained to complete a 3-year plus data set. This time period encompasses the pilot and main (April 2000 -May 2001) field studies while allowing annual mean fields to be computed and seasonal and interannual differences to be identified. This will allow the pilot and main field study periods to be placed within the longer-term temporal context. For example, a multi-year sea surface temperature (SST), sea surface height (SSH) and wind stress curl fields were computed and analyzed to identify mesoscale current features and variability. The locations of fronts and eddies used to determine whether the features observed during the two field studies were typical.

WORK COMPLETED

We have extended our archive of satellite-derived data sets for the South China Sea through the end of 2002. These data sets include high and low resolution sea surface temperature data from the Advanced Very High Resolution Radiometer (AVHRR) from 1990, ocean color images from SeaWiFS from 1997, scatterometer wind fields from QuikSCAT from 1999 and altimeter sea surface height anomalies from TOPEX from 1993. We have added low-resolution sea surface temperature data from the Tropical Rainfall Measuring Mission (TRMM). Wind stress and wind stress curl was derived from the QuikSCAT winds on a 0.25^{o}x0.25^{o} grid. Monthly statistics and climatologies were calculated from each of these data sets. A paper describing the hydrographic variability between 2000 and 2001 was submitted that included mesoscale diagnostics from satellite data.

RESULTS

Our analysis during this past year has continued to focus on integrating altimeter sea surface height data with sea surface temperature data. Figure 1 shows the SST (top) and the sea surface height anomalies (bottom) in the northeast SCS around the ASIAEX study region to the west of the Luzon Strait. Our previous analysis of SST and SSH demonstrated that conditions were considerably different prior to the two field programs in the spring of 2000 and 2001. Analysis of interannual variability shows that the Kuroshio Intrusion has three different forms. The first mode is an eddy-shedding mode where the Kuroshio enters the region past 119^{o} W, forms a loop current that detaches an eddy that translates westward along the shelfbreak. The second mode is similar to the first where the Kuroshio enters the region and forms a loop current, but does not form an eddy. The third mode is a leaping mode, where the Kuroshio only enters the region a short distance and does not form a loop current or eddy. This view is supported in a recent review of the currents in the SCS by Hu *et al*. (2000).

In the winter prior to the 2000 pilot study, the Kuroshio entered the region and formed a loop current (Figure 1) that did not detach an eddy. This loop current formed a large anti-cyclonic circulation that persisted through the spring. In the winter of the following year, a deep penetration of the Kuroshio

was not observed in SST or SSH. This resulted in considerably different conditions for the spring 2001 field program.

Wind stress curl calculated from QuikSCAT was not considerably different during the April/May time frame of the two field programs. The major difference in wind stress curl occurs in the fall and early winter prior to a Kuroshio Intrusion. The maximum negative wind stress curl southwest of Taiwan was much stronger in October 1999 – January 2000 than October 2000 – January 2001. This large negative wind stress curl appears to be necessary for deep penetration of the Kuroshio into the SCS.

IMPACT / APPLICATIONS

Although the circulation of the South China Sea is primarily wind driven, the satellite data has shown that there are considerable interannual variations and these variations can persist on time-scales from weeks to months. There is considerable debate over the frequency and duration of Kuroshio intrusions into the South China Sea. As the time series of satellite data continues to lengthen, we will be able to refine the temporal/spatial behavior and interannual variability of this intrusion and its impact on the general circulation west and south of Taiwan and the shelf-break front.

TRANSITIONS

We have provided remote sensing data to the WHOI and Taiwanese SeaSoar groups in the ASIAEX program to provide broad scale interpretation of their *in situ* data collected in the 2000 pilot and 2001 field programs.

RELATED PROJECTS

The Asian Seas International Acoustics EXperiment (ASIAEX) was developed to investigate the propagation of low frequency sound across the shelfbreak in this region. The insights provided by the Taiwanese and WHOI SeaSoar data (G. Gawarkiewicz, personal communication) have been helpful in our analysis of the satellite data. We are working with Gawarkiewicz and other ASIAEX investigators to provide broad-scale analysis to help in the interpretation of the SeaSoar and moored array data collected during the pilot and main studies. We are also working with D. Chapman to provide sea surface height data for interpretation of various idealized model runs in the South China Sea.

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PUBLICATIONS

Gawarkiewicz, G, J. Wang, M. Caruso, S. Ramp, K. Brink and F. Bahr. Shelfbreak Circulation and Thermohaline Structure in the Northern South China Sea- Contrasting Spring conditions in 2000 and 2001. IEEE J. Oceanic Eng, submitted.

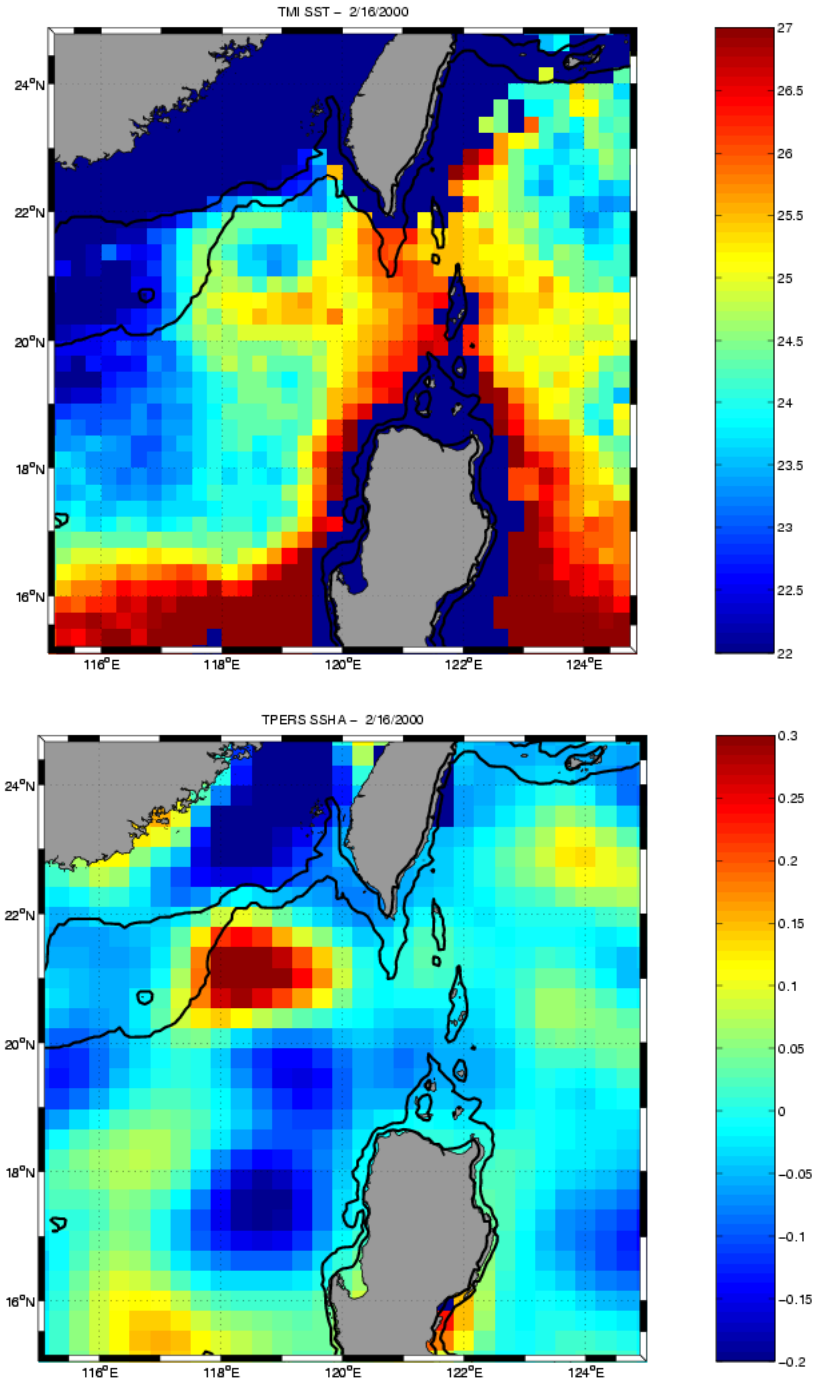

Figure 1. Sea surface temperature (top) and sea surface height anomalies (bottom) showing the large scale anti-cyclonic circulation formed from a Kuroshio intrusion during the winter prior to the 2000 ASIAEX pilot program.